IS 10853-3 (1984): Methods of measurement for radio transmitters, Part 3: Output power and power consumption [LITD 12: Transmitting Equipment for Radio Communication]

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METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

PART 3 OUTPUT POWER AND POWER CONSUMPTION

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METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

PART 3 OUTPUT POWER AND POWER CONSUMPTION

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Indian Standard

METHODS OF MEASUREMENT FOR RADIO TRANSMITTERS

PART 3 OUTPUT POWER AND POWER CONSUMPTION

0. FOREWORD

0.1 This Indian Standard (Part 3) was adopted by the Indian Standards Institution on 31 January 1984, after the draft finalized by the Radio Communications Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to standardize the conditions and methods of measurements to be used to ascertain the performance of a radio transmitter and to make possible the comparison of the results of measurements made by different observors.

0.3 This standard is one of a series of standards on methods of measurement for assessing the performance of radio transmitters for various classes of emission and covers the measurements relating to output power and power consumption. Other characteristics likely to be covered in this series are:

a) General conditions of measurements;

b) Frequency;

c) Band-width, out of band-power;

d) Power of non-essential oscilations;

e) Wanted and unwanted modulation;

f) Amplitude/frequency characteristics and non-linearity distortion in transmitters for radio-telephony and sound broadcasting;

g) Measurements particular to transmitters and transpowers for monochrome and colour television;

h) Cabinet radiation at frequencies between 130 kHz and 1 GHz;

j) Cabinet radiation at frequencies above 1 GHz;

k) Vestigial sideband demodulators for use in conjunction with transmitters or transposers for monochrome or colour television; and

m) Transposers for monochrome and colour television.

0.4 This standard is largely based on IEC Pub 244-1 (1968) 'Methods of measurement for radio transmitters : Part 1 General conditions of measurement, frequency, output power and power consumption', issued by the International Electrotechnical Commission (IEC).

0.5 In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part 3) lays down the methods of measurement of characteristics relating to output power and power consumption as applicable to radio transmitters for all classes of emission.

1.2 This standard (Part 3) shall be read in conjunction with IS : 10853 (Part 1)-1984†.

2. GENERAL

2.1 Dependent on the class of emission the output power of a radio transmitter is expressed in terms of mean power, carrier power or peak envelope power as defined in **2** of IS : 10853 (Part 1)-1984†.

3. MEASUREMENT OF MEAN POWER

3.1 Conditions of Operation — The transmitter as defined in **2.1** shall be operated under the conditions given in **3** of IS : 10853 (Part 1)-1984†. These conditions shall be clearly stated with the results of the measurements.

The characteristics of the test load to which the transmitter is to be connected [*see* **3.2.3** of IS : 10853 (Part 1)-1984†] shall remain constant during the time of the measurement so as to make possible direct calculation or evaluation by comparison of the dissipated power.

It is recommended to verify that other necessary requirements quoted in the relevant equipment specification (for example, the amplitude/modulation frequency characteristic and/or the non-linearity distortion) are satisfied before making final power measurements.

3.2 Condition of Modulation — The condition of modulation given in the relevant equipment specification shall apply.

*Rules for rounding off numerical values (*revised*).

†Methods of measurement for radio transmitters: Part 1 General conditions of measurements.

3.3 Method of Measurement — One of the following methods may be chosen, care being taken to ensure that the time taken for the measurement is such that the condition of **2.5.1** of IS : 10853 (Part 1)-1984* is fulfilled.

3.3.1 *Calorimetric Method* — A resistor which forms the dissipative element of the test load is cooled by a flow of water or other fluid, surrounding the resistance; the fluid itself may also be the dissipative element.

The power dissipated is calculated from the temperature rise, the rate of flow of the coolant or of the fluid in volume units per unit time, and the specific properties of the coolant, according to the following formula:

$$P = \rho . c . \phi . \Delta t$$

where

P = power dissipated, in watts;

ρ = mass density, in kilograms per litre (1 for water);

c = specific heat capacity, in joules per kilogram Celsius degree (4 187 for water);

ϕ = flow, in litres per second; and

Δt = temperature rise, in Celsius degrees.

NOTE 1 — To avoid inaccuracies due to heat radiation and convection losses, it is recommended that Δt be centred on the ambient temperature. For most accurate results, Δt shall be kept as low as practical in view of the variation of the specific properties of the coolant. In this case, however, the precision of the temperature grading and the accuracy of the temperature reading become predominant.

NOTE 2 — Care shall be taken that the indication of the instrument used to determine the temperature rise will not be influenced by rf fields present at the place of these instruments. For example, eddy currents in the column of a mercury thermometer may heat the column independently of the heating of the coolant.

3.3.2 *Comparison Method* — This method may be realized by measuring the temperature rise of the resistor of the test load or of the cell coolant of this resistor by means of a suitable instrument. For comparison, the same temperature rise is then reproduced in the same circuit (or in agreed alternative circuits with identical characteristics) under the same conditions of cooling, using a dc or ac power which may be measured with conventional instruments.

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*Methods of measurement for radio transmitters: Part 1 General conditions of measurements.

NOTE 1 — When the resistor is water-cooled, care shall be taken that the comparison power shall not cause electrolysis and hence influence the measurement.

NOTE 2 — Care shall be taken that the indication of the instuments used to determine the temperature rise will not be influenced by rf field present at the place of these instruments. For example, eddy currents in the column of a mercury thermometer may heat the column independently of the heating of the coolant.

3.3.3 *Resistance Variation Method* — In this method, a temperature dependent resistor (for example, a bolometer or thermistor) in one of the branches of a balanced bridge-circuit constitutes the load or a part thereof. Due to the rf power dissipated, the resistance varies a small amount; this variation is used to unbalance the bridge-circuit, the meter of which may directly be calibrated in power.

Alternatively, the bridge may be restored to balance and the restoring power used as a measure of the rf power after suitable calculations have been made. In this case, the load resistor is restored to its original value, thus avoiding an impedance mismatch.

NOTE 1 — These methods are useful for the measurement of low power (1 mW or less) up to and including Band 10. For high power measurements, accurately calibrated attenuators, directional couplers or similar devices shall be used.

NOTE 2 — When thermistors are used, care shall be taken to avoid errors due to changes of ambient temperature during the time of one measurement. Additional errors may arise, particularly in Band 10 (centimetric waves) and upwards, due to losses in the material (for example, glass) of the enclosure.

3.3.4 *Current-Resistance Method* — The series resistive component R_s of the impedance of the test load shall be determined and the current I to the test load measured, using a true rms, current measuring device the frequency characteristic of which, including any resonance phenomena, is known.

The mean power P is calculated from:

$$P = I^2 R_s$$

NOTE — This method shall not be used in the case of a complex signal when the series resistive component depends substantially on the frequency of the oscillations applied to the test load.

3.3.5 *Voltage-Resistance Method* — The parallel resistive component R_p of the impedance of the test load shall be determined and the voltage V across the test load measured, using a suitable voltage measuring device, the frequency characteristic of which, including any resonance phenomena, is known.

The mean power is calculated from:

$$P = \frac{V^2}{R_p}$$

Care shall be taken that the measured voltage may be evaluated in rms terms, irrespective of the wave-form.

NOTE — This method shall not be used in the case of a complex signal when the parallel resistive component depends substantially on the frequency of the oscillations applied to the test load.

3.3.6 *Directional Coupler Method* — In this method, the incident and reflected power are each determined by using a pair of directional couplers inserted in the transmission line to the test load. The difference between the two measured powers gives the mean power supplied to the terminal load.

The use of such devices for power measurements in the sense of this recommendation assumes that the instrument has been calibrated by comparison with one of the methods mentioned in **3.3.1** and **3.3.2**.

4. MEASUREMENT OF CARRIER POWER

4.1 The carrier power is considered to be a special form of mean power; it shall be measured according to **3.3** in the absence of modulation under the operating conditions given in **3.1**.

5. MEASUREMENT OF PEAK ENVELOPE POWER

5.1 Conditions of Operation — Same as in **3.1**.

5.2 Condition of Modulation — The condition of modulation given in the relevant equipment specification shall apply.

Though the concept of peak envelope power may be applied to all classes of emission, the measurement of peak envelope power of a transmitter is of particular interest to amplitude-modulation single-sideband and independent-sideband transmitters with reduced or suppressed carrier and for vestigial-sideband television transmitters. The recommended modulating signal for the first mentioned group of transmitters is specified in **5.2.1**.

5.2.1 *Conditions of Modulation for Amplitude-Modulation Transmitters for Single Channel and Multi-Channel Telephony, Either Single Sideband or Independent-Sideband and for Multi-Channel Voice-Frequency Telegraphy* — Unless otherwise specified, two modulating sinusoidal oscillations are simultaneously applied at the input to the transmitter, each oscillation giving a rf signal of equal amplitude at the output terminal device.

Supposing that the carrier is sufficiently suppressed and the intermodulation distortion is negligible, the envelope of the rf output signal will sensibly exhibit the form of two intersecting sine curves, as shown in Fig. 1.

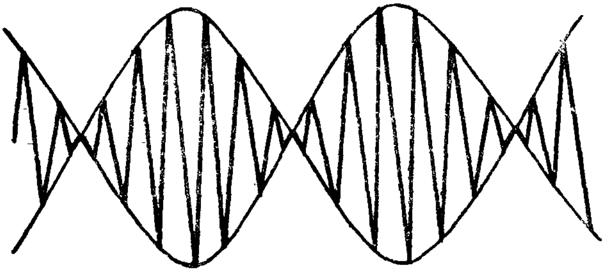

FIG. 1 ENVELOPE OF THE rf OUTPUT SIGNAL OF A SINGLE-SIDEBAND OR INDEPENDENT-SIDEBAND TRANSMITTER MODULATED BY TWO SINUSOIDAL OSCILLATIONS OF EQUAL MAGNITUDE

When measuring the peak envelope power, it shall be verified that the relative amplitude of each intermodulation component with respect to the level of either modulating oscillation, is within the tolerances given in the relevant equipment specification.

NOTE — The measurement of the peak envelope power may be combined to advantage with the measurement of the intermodulation distortion.

5.3 Method of Measurement — An appropriate instrument, connected to the test load, is used to determine the highest crest A_c of the modulation envelope. This instrument may be an inertia-less indicator (for example, a cathode ray oscilloscope) or a peak voltage indicator with suitable time constants.

After the specified modulating signal has been removed, the transmitter is operated under conditions such that a sinusoidal oscillation is supplied to the test load at a level that depends on the power-handling capacity of the transmitter, as follows:

a) The transmitter is preferably operated at a level equal to the peak value A_c initially shown by the indicator. The peak envelope power is then equal to the power in the test load measured according to one of the methods of **3.3**.

b) If the transmitter cannot be operated at a level such that the mean power is equal to the peak envelope power during the period of power measurements, the transmitter is operated at the highest power level that may be maintained without damage to the equipment.

At this power level, the deflection A_m of the indicator is determined and the corresponding power P_m in the test load measured according to one of the methods of **3.3**. Assuming

a linear relation between the deflection of the indicator and the applied voltage, the peak envelope power may be calculated from:

$$\text{Peak envelope power} = P_{\text{m}} \left[\frac{A_{\text{c}}}{A_{\text{m}}} \right]^2$$

5.4 Method of Evaluation — If a method of measurement according to **5.3** cannot be applied, the peak envelope power may be evaluated from the corresponding mean power as follows:

The specified modulating signal is applied at the input to the transmitter and the mean power measured according to one of the methods of **3.3**. The peak envelope power is evaluated from the measured mean power by dividing the mean power by the conversion factor (mean power)/(peak envelope power) for the relevant type of emission and the applied modulating signal.

Example:

For a double-sideband transmitter modulated by a sinusoidal oscillation with a modulation factor m = 1, the conversion factor amounts to 0·375.

For values of m $\leqslant$ 1, the conversion factor may be calculated from:

$$\left(1 + \frac{\text{m}^2}{2} \right) / (1 + \text{m})^2$$

NOTE — It will be noticed that the conversion factors are theoretical figures and that, due to non-linear or other effects in the transmitter, the result of this method may differ from that of the methods described in **3.3**, the latter being in full accordance with the definition of peak envelope power.

6. OUTPUT POWER/RADIO-FREQUENCY CHARACTERISTICS

6.1 When the output power of a transmitter is to be determined as a function of frequency, two principal concepts shall be distinguished.

a) with tuning of the radio-frequency circuits, and

b) without tuning of the radio-frequency circuits of the transmitter or of parts thereof.

6.2 Method of Measurement of Output Power/rf Characteristic Within the Rated Frequency Range — The measurement shall be made at the two boundary frequencies of each range and at any other specified frequency, the transmitter being returned for operation at each chosen frequency.

The mean power or the peak envelope power, whichever is applicable, shall be measured according to one of the methods given in **3** or **5**.

The result shall preferably be given in a graphical form.

6.3 Method of Measurement of Output Power/rf Characteristics Within the Rated Radio-Frequency Pass Band — The measurements shall be made at the frequencies specified in the relevant equipment specification.

The transmitter shall be tuned each time to one of these specified frequencies. At the input of the transmitter as a part thereof, the frequency shall be changed by suitable means to result in a frequency variation within the limits of the rated radio-frequency pass-band, without the transmitter or the part to be measured being retuned.

The mean power or the peak envelope power, whichever is applicable, shall be measured according to one of the methods given in **3** or **5**.

Care shall be taken to avoid a variation in the level of the radio-frequency oscillation at the input of the part to be measured. If this level cannot be kept constant, the magnitude of the variation shall be stated with the results.

The results shall preferably be given in a graphical form.

7. MEASUREMENT OF POWER CONSUMPTION

7.1 Conditions of Operation — The transmitter as defined in **2.1** of IS : 10853 (Part 1)-1984* (*see* Note) shall be operated under the conditions given in **3**. These conditions shall be clearly stated with the results of the measurements.

It is recommended to verify that other necessary requirements quoted in the relevant equipment specification (for example, the output power) are satisfied before measuring the power consumption.

NOTE — For multi-purpose auxiliaries (for example, measuring equipment, monitors and equipment in stand-by position) it is deemed impractical to include the relevant part of their power in the power consumption of the transmitter.

Such exclusions shall be stated with the results of the measurements.

7.2 Condition of Modulation — The condition of modulation given in the relevant equipment specification shall apply.

7.3 Method of Measurement — With respect to power consumption two concepts shall be discerned:

a) input active power (the actual power consumption), and

b) input apparent power.

both to be measured as indicated in **7.3.1** and **7.3.2**.

*Methods of measurement for radio transmitters: Part 1 General conditions of measurements.

If the transmitter is simultaneously supplied from more than one power source, the power consumption shall be measured for each power source.

7.3.1 *Input Active Power*

7.3.1.1 *Input active power for dc primary power supply* — The input active power shall be measured with a wattmeter.

If the requirements of **3.4.2** of IS : 10853 (Part 1)-1984* are met, the input active power may also be measured using voltmeters and amperemeters.

7.3.1.2 *Input active power for ac primary power supply* — When the transmitter is connected to a single-phase supply source, the input active power shall be measured with a wattmeter.

When the transmitter is connected to a three-phase supply system, the input active power shall be measured with three wattmeters. If there is no current in the neutral, the 'two wattmeters method' may be used.

7.3.2 *Input Apparent Power (for ac Primary Power Supply)* — The input apparent power is calculated from the rms line voltages and line currents of the primary power supply of the transmitter under test.

As the rms line currents influence the choice of protecting devices and the size of conductors, it is recommended that these currents be measured, also when no measurement of the input apparent power is required.

For a transmitter connected to a single-phase supply source, the input apparent power amounts to the product of line voltage and line current.

For a transmitter connected to a three-phase supply system, the apparent power is calculated as follows:

a) when the supply system is symmetrically loaded, the input apparent power amounts to the product of line-to-line voltage and line current, multiplied by $\sqrt{3}$;

b) when the supply system is not symmetrically loaded and there is no neutral present, the input apparent power shall be taken as the product of the line-to-line voltage and the sum of the three line currents, divided by $\sqrt{3}$; and

*Methods of measurement for radio transmitters: Part 1 General conditions of measurements.

c) when the three-phase supply system is not symmetrically loaded and a neutral is present, the input apparent power may be taken as the product of the line-to-neutral voltage and the sum of the three line currents.

NOTE — For a three-phase power supply system, with voltages that are not perfectly symmetrical, but within the limits of **3.4.1.2** of IS : 10853 (Part 1)-1984* the arithmetic mean of the three phase-to-phase or phase-to-neutral voltages shall be taken as the line-to-line or the line-to-neutral voltage, respectively.

8. MEASUREMENT OF TOTAL POWER FACTOR

8.1 The total power-factor is determined by calculation.

If the transmitter is simultaneously supplied from more than one primary power source, the total power-factor shall be calculated separately for each power source.

9. MEASUREMENT OF OVERALL EFFICIENCY

9.1 The overall efficiency is determined by calculation after the mean output power (*see* **3**) and the input active power have been measured simultaneously or in rapid succession.

If the transmitter is simultaneously supplied from more than one power source, the input active powers measured at each power source shall be added to obtain the total input active power.

*Methods of measurement for radio transmitters: Part 1 General conditions of measurements.

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